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SEPARATION OF GARNET AND SILLIMANITE FROM AN ANTHOPHYLLITE GNEISS, OBTAINED FROM THE STAR LAKE - ELKEN LAKE AREA, MANITOBA

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SÉPARATION DU GRENAT ET DE LA SILLIMANITE D'UN GNEISS ANTHOPHYLLITE PROVENANT DE LA RÉGION DE STAR LAKE - ELKEN LAKE, MANITOBA

par

P.R.A. Andrews*

RÉSUMÉ

Deux échantillons dont un minerai de grenat et un minerai de sillimanite ont été enrichis en vue d'obtenir des concentrés distincts. Le minerai de grenat a été réduit à une granulométrie de -630 +71 µm et concentré par séparation magnétique par voie sèche dans le but d'obtenir un concentré ayant une teneur en grenat de 93%, à un taux de récupération de 83,2%. Le calibrage ultérieur des concentrés par séparation magnétique, à une granulométrie de -630 +420 µm et une prolongation du traitement au moyen de la classification par jets d'air démontrent qu'il est possible de récupérer un deuxième concentré ayant un contenu en grenat de 83%. Un examen des propriétés minéralogiques des grains de grenat indique que ceux-ci démontrent une fracture bien définie qui ressemble à une ciselure, ce qui les rends proopres à être utilisés comme abrasifs.

Le minerai de sillimanite a été concentré par flottation en vue d'obtenir un concentré ayant une teneur en sillimanite de 64,4% à un taux de récupération de 64,0%. Un examen des propriétés minéralogiques du concentré a démontré que les grains de sillimanite s'y trouvaient dans un rapport de 10:1 à 15:1, ce qui indique qu'il peut probablement être utilisé comme produit d'apport.

Mots-clé: Grenat, Sillimanite, Séparation magnétique, Classification par aération, flottation.

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SEPARATION OF GARNET AND SILLIMANITE FROM AN ANTHOPHYLLITE GNEISS, OBTAINED FROM THE STAR LAKE - ELKEN LAKE AREA, MANITOBA

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ABSTRACT

Two samples, a garnet ore and a sillimanite ore were beneficiated to produce separate concentrates. The garnet ore was sized to -630 +71 µm and concentrated by dry magnetic separation to produce a concentrate analysing 93% garnet at a recovery of 83.2%. Subsequent sizing of the middlings, from magnetic separation, to -630 +420 µm and further treatment by air classification demonstrated that a second concentrate analysing 83% garnet could be recovered. Mineralogical examination indicated that the garnet grains displayed a well formed chisel-like fracture, which is required for abrasive use.

The sillimanite ore was concentrated by flotation to produce a concentrate analysing 64.4% sillimanite with a recovery of 64.0%. Mineralogical examination indicated that the sillimanite grains displayed an aspect ratio of 10:1 to 15:1 which indicated possible filler use.

Keywords: Garnet, sillimanite, magnetic separation, air classification, flotation.

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INTRODUCTION

In January 1987 two separate samples, each consisting of 50 mm to 75 mm hand specimens were delivered to the Mineral Processing Laboratory of CANMET by R. Gunter of the Manitoba Department of Energy and Mines. One sample represented the garnet-rich portion of a garnet-anthophyllite gneiss and the other a quartz-sillimanite portion. The garnet sample weighed ≈ 7 kg. and the sillimanite sample ≈ 10 kg.

The Star Lake - Elken Lake area is 600 km north-west of Winnipeg and approximately 60 km from Flin Flon. The samples were obtained from a layer within the Sheridan quartz-rich gneisses; the gneiss occurs both above and below the garnet anthophyllite. The garnet anthophyllite is composed of three phases: phase 1 is a quartz-garnet-biotite anthophyllite; phase 2 a garnet-anthophyllite with local cordierite and phase 3 an anthophyllite-cordierite (1).

PROCESSING

Head sample

Each sample was stage crushed in the laboratory jaw crusher to -2.5 mm. Representative head samples were prepared for sieve, chemical and mineralogical analyses. A product balance for garnet head material is reported in Table 1 and the results of the mineralogical study in Table 2. A product balance for sillimanite head material is reported in Table 3 and the results of the mineralogical study in Table 4.

Garnet ore: magnetic separation

Although garnet appeared to be 95% liberated at -2.5 mm, very little garnet, in fact, was separated at this size using an Exolon dry magnetic separator. Consequently further size reduction to -630 µm was necessary using a laboratory roll crusher, at which size the garnet was ≈ 100% liberated. After removal of the -70 µm fines, the sample was again passed through the Exolon separator. The middlings and non-magnetic products were screened at 420 and 210 µm to remove silica and sillimanite. Products from magnetic separation and screening were analysed for Fe_2O_3, SiO_2, Al_2O_3, TiO_2, CaO and MgO; results are reported in Table 5.

Garnet ore air: classification

The -530 +420 µm and the -420 +210 µm sized middlings and non-magnetic fractions were further beneficiated using an Alpine zig-zag air classifier. The feed rate and air flow rate were adjusted so that the garnet reported to the sinks, and the lighter quartz and sillimanite to the floats. After visual assessment, some floats and sinks products were repassed to achieve a better separation. The results are reported in Table 6.

Sillimanite ore: magnetic separation

Since liberation was ≈ 95% at -2.5 mm, magnetic separation using the Exolon dry magnetic separator was carried out on the -2.5 mm +630 µm and -630+160 µm size fractions. The -160 µm material was removed as fines. All products were analysed for Fe_2O_3, SiO_2, Al_2O_3, TiO_2, CaO and MgO; the results are reported in Table 7.

Sillimanite ore: air classification

Although most of the biotite was removed by magnetic separation, a more weakly magnetic intermediate phase phlogopite-biotite remained. A 500 g, re-constituted head sample (magnetics, non-magnetics and -160 µm fraction) was sized at 1400 µm, 500 µm, 230 µm and 100 µm, and each portion treated in the zig-zag air classifier. The feed and air flow rates were adjusted so that the biotite-phlogopite material reported to the sink products and the lighter quartz and sillimanite reported to the floats. All products were analysed for the principal oxides; results are reported in Table 8.

Sillimanite ore: flotation

The remaining magnetics, non-magnetics and minus 160 µm material were each divided into two portions. One portion of each was combined to make a re-constituted head, which was used as flotation feed material.

As a comparison, flotation was also conducted on the remaining portions of re-combined non-magnetic and -160 µm fractions, the magnetic portion being discarded.

Each flotation feed portion was crushed to -630 µm in a laboratory roll crusher and divided into 500 g lots. The flotation procedure involved grinding at 50% solids to 67% -70 µm in a laboratory jar mill using ceramic grinding media. Flotation of sillimanite was conducted at 30% solids in a laboratory Denver D1 flotation cell. Two flotation treatment routes were explored; flotation at pH 9.7 using sodium hydroxide as pH modifier and sodium oleate as collector [2], and flotation at pH 2.5 to 3.0 using Armac T (tallow amine acetate). Aerofloat 840 (petroleum sulphonate) collector was used in one test to float iron oxide minerals. The effect of sodium carbonate as pH modifier and slime dispersant, and sodium silicate as slime dispersant and quartz depressant were briefly examined.

Product balances of all flotation tests are reported in Table 9, and reagent consumption data in Table 10.

RESULTS

Garnet ore

A -630 +70 µm garnet concentrate analysing 27.9% Fe_2O_3, which represented a grade of 93% with a recovery of 83.2% was obtained by magnetic separation. Visual assessment of the middlings and non-magnetic fractions indicated that garnet was concentrating in the coarser sizes. Analysis of the -630 +420 µm middling fraction indicated 17.27% Fe_2O_3, which corresponded to about 60% garnet. It is possible that this trend also occurred in the -630 +70 µm garnet concentrate (magnetic fraction), but this was not investigated. The effect of air classification on each sized fraction of middlings indicated that garnet in the -630 +420 µm fraction could be upgraded to 25.8% Fe_2O_3 or 83% garnet. There was a slight concentration of garnet in the -420 +210 µm fraction.

Mineralogical examination of the garnet concentrates revealed that the principal impurity was sillimanite; quartz and biotite were present in minor

amounts. These impurities could be further reduced by using a more powerful magnetic separator. A sample of the -630 +70 µm garnet concentrate was passed through a Perm-roll magnetic separator and further sillimanite was removed. Garnet concentrate grains displayed a well formed chisel-like fracture which is preferred for abrasive material.

Sillimanite ore

Magnetic separation indicated that 42.2% of the iron oxides content, chiefly contained in the biotite, was removed. The removal of titanium minerals was slightly better, at 51.4%. Similar performance was experienced with air classification where 41.9% of the iron oxides, and 50.1% of the titanium minerals were removed. In neither beneficiation procedure was there any noticeable concentration of the sillimanite.

Flotation was more successful in concentrating sillimanite. A total of twelve tests were conducted; Tests 1 to 6 were carried out on original ore and Tests 7 to 10 on material from which the iron oxide minerals had been removed.

1. Original ore

In Test 1, Aerofloat 840 was relatively unsuccessful in floating iron oxide minerals, although Aerofloat 840 did float 49.6% of the sillimanite at an estimated grade of 65.7%*. In Test 2, Armac T floated 56.6% of the iron oxide minerals and 61.2% of the sillimanite for a reduced grade of 59.6% sillimanite. In Tests 3 and 4, reduced concentration of Armac T floated less sillimanite. The relatively poor performance of Tests 3 and 4 is also attributable to excessive slime losses (28.0% sillimanite in Tests 3 and 26.4% sillimanite in Test 4).

From Test 5 onwards only one collector was used to float sillimanite. In Tests 1 to 4, two collectors were used; it was observed, however, that most of the sillimanite was floated by the

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* Since sillimanite is the main source of Al_2O_3, the Al_2O_3 analyses and distribution figures are used to indicate the grade and recovery of sillimanite. The grade values are obtained by multiplying the Al_2O_3 analyses by a factor of 1.59.

The possible presence of biotite will not appreciably alter the Al_2O_3 content since biotite accounts for only 10% of the ore, and biotite contains only ≈ 10% Al_2O_3.

first collector. In addition, the desliming cyclone was adjusted to reduce the slime fraction overflow to the minimum weight loss possible, consistent with efficient desliming. An increase in the concentration of Armac T collector in Test 5, to 936 g/t, resulted in a sillimanite concentrate analysing 51.7% sillimanite, with a recovery of 73.1%. The iron oxide content, however, was high at 76.5%. A comparative collector, sodium oleate, was used in Test 6, where a sillimanite concentrate analysing 56.6% sillimanite was obtained with a recovery of 72.2%; the iron oxide content was lower at 60.4%.

2. Iron oxide minerals removed

Similar results to Test 6 were obtained in Test 7, where sodium oleate was again used as collector to produce a concentrate analysing 57.5% sillimanite, with a recovery of 66.9%. In Test 8, Armac T was used as the collector, but no improvement over Test 5 results was obtained. In Test 9, it was decided to float without prior desliming using sodium oleate as collector. A concentrate analysing 55.4% sillimanite was obtained with a recovery of 65.5%. This result, which is similar to Test 7, indicates that desliming may not be necessary. Poor results were obtained in Test 10 since sillimanite was also depressed by the quartz depressant sodium silicate.

A final test, Test 11, included a cleaning stage which increased the final concentrate grade to 64.4% sillimanite for a recovery of 64.0%. Mineralogical examination indicated that the sillimanite grains displayed an aspect ratio of 10:1 to 15:1, which indicated possible filler use. For ceramic and refractory use sillimanite should have a blocky texture (lenticular shape).

CONCLUSIONS

Garnet ore

A -630 +70 µm concentrate analysing 27.9% Fe_2O_3, and representing a grade of 93% garnet with a recovery of 83.2%, was obtained by magnetic separation.

After sizing the middlings from magnetic separation to -630 +420 µm, further treatment by air classification indicated that a garnet concentrate analysing 25.8% Fe_2O_3, representing a grade of 83% garnet, could be obtained.

Sillimanite ore

A combination of grinding to 67% -70 µm and flotation produced a concentrate analysing 40.5% Al_2O_3, representing a grade of 64.4% sillimanite with a recovery of 64.0%.

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Table 1. Garnet one head sample product balance.

Size fraction µm	Analysis %						Distribution %				
	Wt %	Fe_2O_3	TiO_2	SiO_2	Al_2O_3	MgO	Fe_2O_3	TiO_2	SiO_2	Al_2O_3	MgO
-2500 +630	55.4	17.9	0.44	59.8	13.4	7.01	55.0	52.7	55.7	54.1	54.1
-630 +315	17.2	17.2	0.41	61.3	13.3	7.05	16.4	15.4	17.7	16.7	16.9
-315 +200	9.0	17.9	0.48	59.9	13.9	7.14	8.9	9.2	9.2	9.0	9.0
-200 +160	3.1	18.7	0.52	58.2	14.5	7.39	3.2	3.4	3.0	3.3	3.2
-160 +70	8.9	18.8	0.59	57.6	14.6	7.56	9.3	11.5	8.6	9.5	9.4
-70	6.4	20.1	0.55	54.3	15.9	8.35	7.2	7.8	5.8	7.4	7.4
Head (calculated)	100.0	18.0	0.46	59.5	13.7	7.18	100.0	100.0	100.0	100.0	100.0

Table 2. Garnet ore mineral identification and modal analysis

Size fraction	Description
-2500 +630 µm	Liberation was = 95%.
-630 +70 µm	Liberation essentially complete and the mineralogical composition is as follows: 45% garnet possibly as the almandine variety, pinkish-red, translucent, with a well defined hockly-chisel point fracture. 35% clear, light yellow translucent quartz. 15% brown-green a cicular subhedral aggregates of sillimanite. 5% dark brown tabular anhedral plates of biotite.

Trace amounts of specular hematite were found associated with the quartz. At approximately -315 µm the garnet content appeared to decrease inversely as the sillimanite content increased.

Table 3. Sillimanite ore head sample product balance.

Size fraction	Analysis %				Distribution %		
	Wt %	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3
µm							
-2500 +630	35.7	1.39	67.9	14.9	40.7	34.3	28.0
-630 +315	20.3	1.37	75.5	16.0	22.8	21.7	17.1
-315 +200	9.8	1.26	76.7	16.3	10.0	10.6	8.4
-200 +160	3.9	1.19	73.6	18.1	3.8	4.1	3.7
-160 +70	12.3	1.00	74.5	20.7	10.1	13.0	13.4
-70	18.0	0.85	63.8	31.1	12.6	16.3	29.4
Head (calculated)	100.0	1.22	70.6	19.0	100.0	100.0	100.0
Head (measured)	-	1.16	76.4	18.8	-	-	-

Table 4. Sillimanite ore mineral identification and modal analysis.

Size fraction	Description
-2500 +630 µm	Liberation was ≈ 95%.
-630 +71 µm	Liberation was virtually complete; mineralogical composition is as follows: 60% quartz as clear vitreous grains with a pronounced conchoidal fracture; some grains were milky-white to pale yellow. 30% sillimanite, mostly as milky white nematoblastic parallel groups of acicular euhedral crystals. Compound aspect ratios vary from 2:1 to 15:1; single crystals in the finer sizes are more consistent and average 8:1. Some few sillimanite grains are dark brown to light green in colour. 9% biotite as anhedral dark brown platy flakes. Some flakes display sillimanite intergrowths protruding from the tabular face. 1% garnet, pink to clear vitreous and anhedral.

There is no visible concentration of sillimanite in any size fraction.

Table 5. Magnetic separation and sizing results for garnet ore.

Products	Analysis %					Distribution %				
	Wt %	Fe_2O_3	SiO_2	Al_2O_3	MgO	TiO_2	Fe_2O_3	SiO_2	Al_2O_3	MgO	TiO_2
Magnetics	55.4	27.9	44.2	19.7	10.90	0.41	83.2	40.4	78.2	78.9	48.2
Middlings	13.7	12.1	70.9	10.3	6.05	0.65	8.9	16.1	10.1	10.8	18.9
Non-Magnetics	30.9	4.8	85.3	5.3	2.56	0.50	7.9	43.5	11.7	10.3	32.9
Head (calculated)	100.0	18.6	60.6	14.0	7.66	0.47	100.0	100.0	100.0	100.0	100.0
Middlings											
-630 +420 µm	6.2	17.3	59.0	13.5	10.38	0.57	5.8	6.1	6.0	8.4	7.4
-420 +210	1.4	8.7	74.8	8.7	6.20	0.66	0.6	1.7	0.9	1.1	1.9
-210	6.1	7.6	82.1	7.4	1.61	0.74	2.5	8.3	3.2	1.3	9.6
Head (measured)	13.7	12.1	70.9	10.3	6.05	0.65	8.9	16.1	10.1	10.8	18.9
Non-magnetics											
-630 +420 µm	17.5	7.2	81.1	6.7	3.71	0.33	6.8	23.4	8.4	8.5	12.3
-420 +210	9.5	1.9	87.8	3.6	1.06	0.48	1.0	13.8	2.4	1.3	9.8
-210	3.9	0.7	98.1	3.1	1.05	1.31	0.1	6.3	0.9	0.5	10.8
Head (measured)	30.9	4.8	85.3	5.3	2.56	0.50	7.9	43.5	11.7	10.3	32.9

Table 6. Zig-Zag air classifier results for garnet ore.

Products	Analysis %						Distribution %				
	Wt %	Fe_2O_3	SiO_2	Al_2O_3	MgO	TiO_2	Fe_2O_3	SiO_2	Al_2O_3	MgO	TiO_2
+420 µm Middlings											
Air sink 2	20.0	28.8	49.0	18.1	9.50	0.35	29.9	16.6	26.8	18.3	12.3
Air float 1	9.1	12.3	54.3	13.8	13.70	1.52	6.5	8.4	9.3	12.0	24.2
Air float 2	70.9	15.5	62.4	12.2	10.20	0.51	63.6	75.0	63.9	69.7	63.5
Head (calculated)	100.0	17.3	59.0	13.5	10.38	0.57	100.0	100.0	100.0	100.0	100.0
-420 +210 µm Middlings											
Air sink 2	51.6	11.5	72.8	9.7	6.21	0.57	68.4	50.2	58.0	51.7	44.4
Air float 1	48.4	5.7	76.9	7.5	6.19	0.76	31.6	49.8	42.0	48.3	55.6
Head (calculated)	100.0	8.7	74.8	8.7	6.20	0.66	100.0	100.0	100.0	100.0	100.0
+420 µm Non-Magnetics											
Air sink 2	90.4	7.5	81.3	6.7	3.50	0.28	93.7	90.6	89.8	85.3	76.9
Air float 2	9.6	4.7	79.0	7.1	5.70	0.79	6.3	9.4	10.2	14.7	23.1
Head (calculated)	100.0	7.2	81.1	6.7	3.71	0.33	100.0	100.0	100.0	100.0	100.0
-420 +210 µm Non-Mags											
Air sink 1	72.8	2.0	87.0	3.5	1.03	0.48	74.6	72.1	71.2	71.1	78.1
Air float 1	27.2	1.8	90.1	3.8	1.12	0.36	25.4	27.9	28.8	28.9	21.9
Head (calculated)	100.0	1.9	87.8	3.6	1.06	0.48	100.0	100.0	100.0	100.0	100.0

Table 7. Magnetic separation and sizing results for sillimanite ore.

Products	Analysis %				Distribution %		
	Wt %	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3
-2500 +630 µm magnetics	3.8	8.34	57.5	21.4	27.7	3.4	4.4
-2500 +630 µm non-magnetics	37.1	0.65	56.6	12.5	21.0	31.7	25.4
-630 +160 µm magnetics	1.2	13.80	45.1	24.7	14.5	0.8	1.6
-630 +160 µm non-magnetics	28.8	0.54	78.7	16.4	13.7	34.2	25.8
-160 µm	29.1	0.91	68.2	26.9	23.1	29.9	42.8
Head (calculated)	100.0	1.15	66.2	18.3	100.0	100.0	100.0

Table 8. Zig-Zag air classifier results for sillimanite ore.

Products	Analysis %				Distribution %		
	Wt %	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3
-2500 +1400 µm floats	0.9	5.20	65.2	21.1	4.3	0.8	1.2
-2500 +1400 µm sinks	12.8	0.68	75.6	12.9	7.8	12.6	10.1
-1400 +500 µm floats	10.5	3.05	75.9	16.9	28.8	10.4	10.9
-1400 +500 µm sinks	40.4	0.83	78.5	17.1	30.2	41.2	42.3
-500 +230 µm floats	3.0	2.70	77.3	15.9	7.2	3.0	2.9
-500 +230 µm sinks	18.5	0.72	77.3	15.6	11.9	18.5	17.6
-230 +100 µm floats	1.0	1.84	80.4	14.4	1.6	1.0	0.8
-230 +100 µm sinks	12.9	0.71	74.3	18.0	8.2	12.5	14.2
Head (calculated)	100.0	1.11	77.0	16.4	100.0	100.0	100.0
Head (measured)	-	1.16	76.4	18.8	-	-	-

Table 9. Product balances of silimanite ore flotation tests.

Test No.	Products	Analysis %				Distribution %		
		Wt %	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3
1	Slime	9.1	1.37	81.3	21.0	10.8	10.3	10.2
	1st iron oxide float	9.6	1.42	49.3	39.2	11.8	6.6	20.0
	2nd iron oxide float	13.0	1.42	48.1	43.0	15.9	8.7	29.6
	1st sillimanite float	11.9	1.99	65.0	25.7	20.4	10.8	16.3
	2nd sillimanite float	15.8	1.97	75.9	17.1	26.8	16.7	14.4
	Rougher tails	40.6	0.41	83.1	4.4	14.3	46.9	9.5
	Head (measured)	100.0	1.16	71.9	18.8	100.0	100.0	100.0
2	Slime	19.4	1.75	83.3	18.6	29.3	21.1	19.2
	1st iron oxide float	11.3	3.92	47.3	34.8	38.2	7.0	20.9
	2nd iron oxide float	19.3	1.11	56.3	39.2	18.4	14.2	40.3
	1st sillimanite float	6.0	0.37	86.4	10.0	1.9	6.8	3.2
	2nd sillimanite float	27.7	0.32	88.0	7.1	7.7	31.9	10.4
	Rougher tails	16.3	0.32	88.8	6.9	4.5	18.9	6.0
	Head (measured)	100.0	1.16	76.4	18.8	100.0	100.0	100.0
3	Slime	26.6	1.67	84.7	19.8	38.3	29.5	28.0
	1st iron oxide float	15.0	2.98	42.5	42.1	38.5	8.3	33.6
	1st sillimanite float	8.9	0.40	82.4	13.2	3.1	9.6	6.3
	2nd sillimanite float	11.3	0.54	78.6	19.1	5.3	11.6	11.5
	Rougher tails	38.2	0.45	81.9	10.2	14.8	41.0	20.6
	Head (measured)	100.0	1.16	76.4	18.8	100.0	100.0	100.0
4	Slime	23.4	1.73	80.8	21.2	34.9	24.7	26.4
	1st iron oxide float	11.5	3.49	39.1	42.2	34.6	5.9	25.8
	1st sillimanite float	5.5	0.55	76.3	15.3	2.6	5.5	4.5
	2nd sillimanite float	31.4	0.53	77.3	17.8	14.3	31.8	29.7
	Rouhger tails	28.2	0.56	87.0	9.0	13.6	32.1	13.6
	Head (measured)	100.0	1.16	76.4	18.8	100.0	100.0	100.0

Table 9. (cont'd)

Test No.	Products	Analysis %				Distribution %		
		Wt %	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3
5	Slime	8.5	2.09	67.4	20.3	15.1	8.3	9.4
	1st rgh. float	20.4	3.39	53.8	29.9	58.5	15.9	33.2
	2nd rgh. float	20.9	1.02	53.4	35.0	18.0	16.2	39.9
	Rougher tails	50.2	0.20	82.0	6.4	8.4	59.6	17.5
	Head (calculated)	100.0	1.18	69.0	18.3	100.0	100.0	100.0
6	Slime	8.1	1.77	68.4	19.0	13.4	7.9	8.3
	1st rgh. float	23.8	1.60	52.2	36.8	35.6	17.7	46.9
	2nd rgh. float	14.1	1.89	62.5	33.5	24.8	12.6	25.3
	Rougher tails	54.0	0.52	80.4	6.8	26.2	61.8	19.5
	Head (calculated)	100.0	1.07	70.2	18.7	100.0	100.0	100.0
7	Slime	7.8	1.02	71.1	19.5	12.6	7.7	8.2
	1st rgh. float	20.9	0.94	46.3	35.5	30.8	13.4	39.7
	2nd rgh. float	13.7	1.03	60.0	37.1	22.2	11.4	27.2
	Rougher tails	57.6	0.38	84.6	8.1	34.4	67.5	24.9
	Head (calculated)	100.0	0.64	72.2	18.7	100.0	100.0	100.0
8	Slime	7.7	0.97	72.1	20.0	12.0	7.5	8.1
	1st rgh. float	20.5	1.55	59.3	28.9	50.8	16.3	31.3
	2nd rgh. float	20.9	0.65	59.4	30.9	21.7	16.7	34.2
	Rougher tails	50.9	0.19	87.1	9.8	15.5	59.5	26.4
	Head (calculated)	100.0	0.63	74.5	18.9	100.0	100.0	100.0
9	1st rgh. float	21.9	1.01	53.8	35.1	37.1	15.4	39.9
	2nd rgh. float	14.3	1.06	62.5	34.5	25.5	11.7	25.6
	Rougher tails	63.8	0.35	87.6	10.4	37.4	72.9	34.5
	Head (calculated)	100.0	0.60	76.6	19.3	100.0	100.0	100.0

Table 9. (cont'd)

Test No.	Products	Analysis %				Distribution %		
		Wt %	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3
10	1st rgh. float	6.7	0.93	63.4	24.7	10.2	5.6	8.6
	2nd rgh. float	4.6	0.83	69.6	24.1	2.3	4.2	5.7
	Rougher tails	88.7	0.60	77.5	18.7	87.5	90.2	85.7
	Head (calculated)	100.0	0.61	76.2	19.4	100.0	100.0	100.0
11	1st rgh. float	29.9	1.14	49.8	40.5	54.7	19.5	64.0
	2nd rgh. float	26.8	0.73	78.1	17.6	31.4	27.5	24.9
	Rougher tails	43.3	0.20	93.1	4.8	13.9	53.0	11.1
	Head (calculated)	100.0	0.62	76.1	18.9	100.0	100.0	100.0

Table 10. Flotation parameter data and reagent concentrations.

Test No.	Flotation stage	No of stage	Cond. time min.	Float time min.	pH	Pulp density % s	Impeller speed r.p.m.	Collectors: Aero 840 g/t	Collectors: Sodium Oleate kg/t	Collectors: Armac T g/t	Sodium Silicate kg/t	Sodium Carbonate kg/t	H_2SO_4 kg/t	Sodium hydroxide g/t	M.I.B.C. g/t
1	Rougher (iron oxide)	2	8	6	3.4	30	1200	550.0	-	-	-	-	0.77	-	237.6
	Rougher (sillimanite)	2	8	4	9.6	30	1200	-	550.0	-	-	-	-	726.2	79.2
2	Rougher (iron oxide)	2	8	5	3.0	30	1200	-	-	620.0	-	-	0.59	-	198.8
	Rougher (sillimanite)	2	8	4	9.7	30	1200	-	620.0	-	-	-	-	943.4	89.2
3	Rougher (iron oxide)	1	5	6	2.5	30	1200	-	-	340.4	-	-	3.11	-	98.0
	Rougher (sillimanite)	2	9	7	9.7	30	1200	-	680.8	-	-	10.89	-	-	98.0
4	Rougher (iron oxide)	1	4	4	2.5	30	1200	-	-	456.8	-	-	2.45	-	94.0
	Rougher (sillimanite)	2	8	7	9.8	30	1200	-	652.4	-	-	-	-	1853.3	141.0
5	Rougher (iron oxide)	2	8	9	3.0	30	1200	-	-	936.0	-	-	4.19	-	224.6
6	Rougher (sillimanite)	2	8	11	9.7	30	1200	-	755.8	-	-	-	-	403.1	181.4
7	Rougher (sillimanite)	2	8	8	9.8	30	1200	-	720.6	-	-	-	-	487.6	259.5
8	Rougher (iron oxide)	2	8	9	3.0	30	1200	-	-	730.6	-	-	2.92	-	219.2
9	Rougher (sillimanite)	2	8	9	9.7	30	1200	-	643.2	-	-	-	-	499.6	193.0
10	Rougher (sillimanite)	2	8	7	9.7	30	1200	-	652.0	-	10.87	-	3.12	267.3	352.1
11	Rougher (sillimanite)	2	16	18	9.7	30	1200	-	466.9	-	-	-	-	490.2	235.4
	Cleaner (sillimanite)	2	16	10	9.7	30	1200	-	-	-	-	-	-	409.9	201.6